# Challenge # 2. Logistics and Compatibility with Existing Infrastructure Throughout Supply Chain

1. Production location
2. Transporting feedstocks and fuel
3. Aging of oil
4. Oil storage
5. Infrastructure compatible fuels
6. How do we identify low-cost options?

# Logistics



| System Component | Options | Variables | |
|---|---|---|---|
| Biomass Production | Forestry residues<br>Energy crops<br>Felling<br>Chipping<br>Baling | Harvesting window<br>Production costs (location dependent) | |
| Pretreatment | Storage<br>Chipping<br>Drying<br>Pelletising | Equipment capacity<br>Capital and O&M<br>Energy consumption (power, fuel, heat) | Load factor<br>Dry matter loss<br>Moisture loss |
| Transport | Truck<br>Train<br>Ship | Transport distance<br>Speed<br>Capacity<br>Product weight<br>Product volume | Capital and O&M<br>Fuel consumption<br>Load factor<br>Transfer time & costs |
| Storage & Use | Above ground tanks<br>Underground tanks | Capital and O&M<br>Combustion efficiency | |

Adapted from VTT Research Notes 2312

# Bio-oil Stabilization and Upgrading – Technical Challenges



- Fast pyrolysis derived bio-oil has many undesirable properties, the main technical barrier is the removal of oxygen:
  - High O content: 35-40%
  - High water content: 15-30 wt%
  - High acidity; pH = 2.5, TAN > 100 mg KOH/g oil
  - Unstable (phase separation, reactions)
  - Low HHV: 16-19 MJ/kg
  - Distillation residue: up to 50 wt %

*Energy & Fuels* 18: 590-598 (2004)

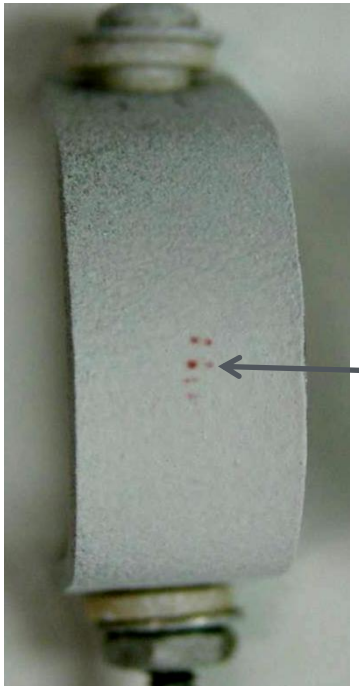
**Fast pyrolysis bio-oil**

# Corrosion Cracking Of Samples Exposed In Bio-Oil



- Through wall cracks have been found in carbon steel and 2¼ Cr-1 Mo samples after exposure at 50ºC
- Samples of 304L and 18 Cr – 2 Mo stainless steels developed crack indications after 750 hr at 50ºC
- Exposure of these samples is being continued to determine if more extensive cracking will develop

Through wall crack in carbon steel

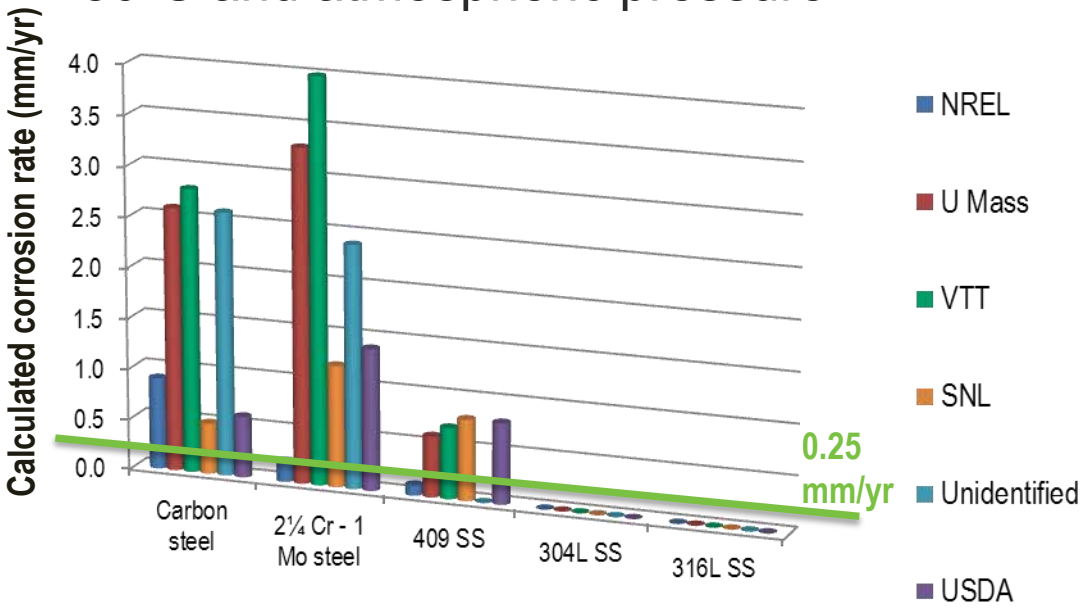


Crack indications in stainless steel

# Effect Of Raw Bio-Oil On Metallic Structural Materials



- Studies are being conducted to assess the extent of corrosion and cracking caused by bio-oil of metallic structural materials used in production, storage, transport and further processing of bio-oil
- Exposure of five potential structural materials in and above pyrolysis oil at 50˚C and atmospheric pressure




Calculated corrosion rate (mm/yr) for samples exposed 500 hr in pyrolysis oil from 6 different sources

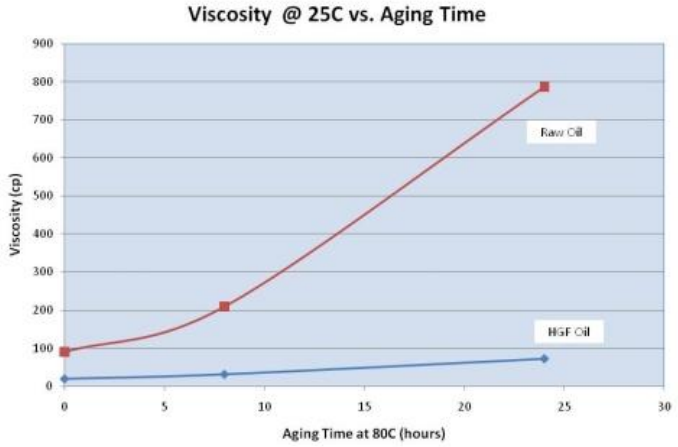
0.25 mm/yr is approximate limit for components expected to have a lifetime of no more than 10 years

- Biomass derived bio-oil can potentially be treated to make it compatible with common materials of construction
- Fully upgraded bio-oils (<0.5% $O_2$ content) showed no damage on any material
- Bio-oil conditioning is expected to add some cost but is not expected to be a show-stopper

# Bio-Oil Conditioning



- Hot bio-oil vapor filtration
  - Lower ash and Group I metals
- High pressure thermal treatment
  - Can reduce oxygen by ~ 50% (dry basis)
- Low-severity hydrotreating
  - Can reduce bio-oil oxygen content to 5-8%




**Accelerated aging at 80°C shows greater stability for filtrate**

**Ceramic Filter**

**0 Cycles** **1500 Cycles**

# Flammability & Toxicity – Transportation Guidelines

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

| Property | Potential Transportation Classification | Existing Test Methods | Limit Values | Results: Tox 21 Bio-Oil | Conclusion | Applicable Transportation Classification |
|---|---|---|---|---|---|---|
| Flammability | Class 3, Flammable Liquids | Flashpoint | ≤60°C | This method does not apply to bio-oil | If the product does not sustain combustion, it does not need to be classified as flammable, regardless of the flashpoint result | N/A |
| | | Sustained Combustibility | Does not sustain combustibility | Does not sustain combustibility | | |
| Corrosivity | Class 8, Corrosive Substance | OECD Tests | Full thickness destruction of intact skin tissue | Slightly corrosive for rabbit, pH > 2.5 | Probably slightly corrosive | Class 8, Packing Group III |
| | | UN Test Manual | Metal corrosion of steel/aluminum | Not corrosive for steel. Corrosive for aluminum | | |
| Toxicity | Class 6.1, Toxic Substances | Rat Testing | $LD_{50}$≤300 mg/kg (oral) | $LD_{50}$>2000 mg/kg (oral, rat) | Not classified as toxic substance | N/A |

**Source: Oasmaa, A., et.al., 2012. "Guidelines for Transportation, Handling, and Use of fast Pyrolysis Bio-Oil. Part 1 – Flammability and Toxicity. Energy & Fuels. DOI: 10.1021/ef3004184d**

# Flammability & Toxicity – Transportation Guidelines (2)



| Property | Potential Transportation Classification | Existing Test Methods | Limit Values | Results: Tox 21 Bio-Oil | Conclusion | Applicable Transportation Classification |
|---|---|---|---|---|---|---|
| Environmentally Hazardous | Class 9, Miscellaneous dangerous goods | Aquatic toxicity | 10 mg/l | Algae 72 h: 100 mg/l | Not environmentally hazardous | N/A |
| | | Bioaccumulation | 10 mg/l | Daphnia 48 h: 100 mg/l | | |
| | | Degradation | OECD Tests | Biodegradability 28 days: 42% | Not classified as environmentally hazardous | |

**Source: Oasmaa, A., et.al., 2012. "Guidelines for Transportation, Handling, and Use of fast Pyrolysis Bio-Oil. Part 1 – Flammability and Toxicity. Energy & Fuels. DOI: 10.1021/ef300418d**

# Standards & Recommended Practices



## Partial list, primarily related to fuel storage and inspection thereof

- API Recommended Practices
  - 1007, 1604, 1615, 1621, 1626, 1627, 1628, 1629, 1631, 1632, 1635, 2003, 2005, 2610
- ASTM Standards
  - 1430, 1526, 1599, 1739, 1912, 1943, 1990
- NACE Standards
  - RP0169, RP0177, RP0178, RP0184, RP0285, RP0288, TM0101, TM0479
- Steel Tank Institute (STI) Standards
  - R892, R922, R972, P3, F894 ACT100, F961ACT100U
- NFPA Standards
  - 30, 30A, 326, 329, 385
- NLPA Standard 631
- UL Standards
  - 58, 142, 971, 1316, 1746

# Challenge #2



**Production Location**

**Feedstock Transportation**

**Fuel Transportation**

**Fuel Storage & Handling**